



中国科学院高能物理研究所

# 季度考核报告

王书栋

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2023.01.06

高能量组研究生季度考核  
实验物理中心

# 研究工作

- 深度学习算法在CEPC上Higgs衰变事例分类的应用
- ATLAS上boosted W/Z喷注标记研究
- ATLAS ITk 硅微条探测器项目中IHEP站点生产流程管理网页开发
- ATLAS ITk硅微条探测器CSNS站点辐照测试研究中ColdBox的设计
- 其他工作
  - CEPC上顶夸克电弱耦合测量研究
  - ATLAS ITk 硅微条探测器模块生产

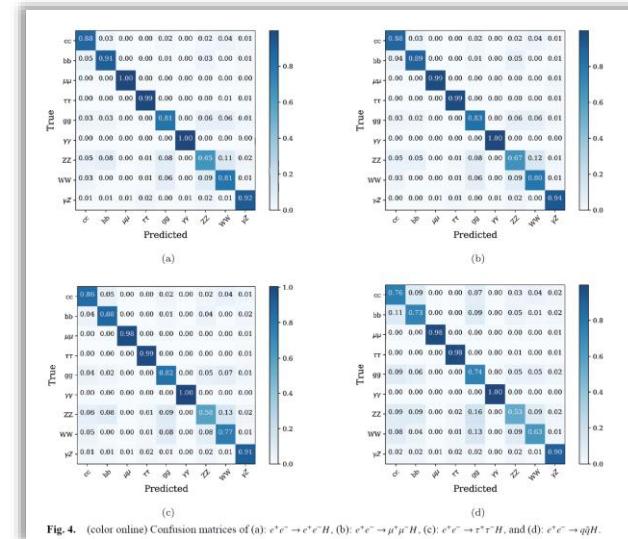
# 深度学习算法在CEPC上Higgs衰变事例分类的应用

- 动机：**我们想要在CEPC上同时对Higgs衰变中可行的（统计量足够高）9个道( $H \rightarrow b\bar{b}$ ,  $c\bar{c}, \mu^+\mu^-$ ,  $\tau^+\tau^-$ ,  $gg, \gamma\gamma, WW^*, ZZ^*, Z\gamma$ )进行分支比测量，以期取得测量精度的提高，而解决这些道之间的相互污染是个重要问题，即提高衰变末态鉴别效率非常重要。

$$\begin{pmatrix} n_1 \\ n_2 \\ \vdots \\ n_9 \end{pmatrix} = \begin{pmatrix} \epsilon_{11} & \epsilon_{12} & \cdots & \epsilon_{19} \\ \epsilon_{21} & \epsilon_{22} & \cdots & \epsilon_{29} \\ \vdots & \vdots & \ddots & \vdots \\ \epsilon_{91} & \epsilon_{92} & \cdots & \epsilon_{99} \end{pmatrix} \begin{pmatrix} N_1 \\ N_2 \\ \vdots \\ N_9 \end{pmatrix}$$

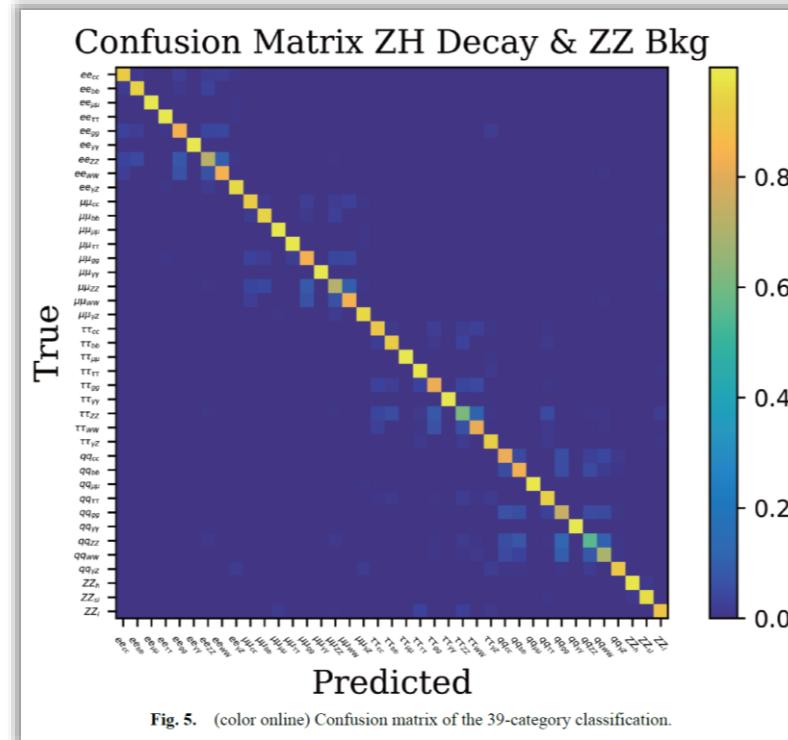
- 同时测量这9个道，鉴别效率成为矩阵的形式，而该矩阵的 $(\det)^2$ 与分支比的cov成反比  $\Sigma^B \propto \frac{1}{(N_t^e)^2 |\mathbf{E}|^2}$
- 目的：**研究应用深度学习方法同时进行Higgs衰变末态多分类，提高Higgs衰变事例鉴别分类效率 这一途径的可行性
- 方法：**使用CEPC软件框架进行快速模拟产生MC样本，将事例中每个粒子的四动量，电荷，IP和PID作为输入变量，应用Particle Flow Network(PFN)分别对4个Higgs产生模式( $e^+e^-H, \mu^+\mu^-H, \tau^+\tau^-H, q\bar{q}H$ )的9个衰变道进行分类，应用ParticleNet对前述共36个道以及3个主要不可约本底过程( $e^+e^- \rightarrow ZZ_l, e^+e^- \rightarrow ZZ_{sl}, e^+e^- \rightarrow ZZ_h$ )进行分类，并优化超参数以提高性能。
- 结果：**用PFN对4个Higgs产生模式( $e^+e^-H, \mu^+\mu^-H, \tau^+\tau^-H, q\bar{q}H$ )的9个衰变道进行分类：

Decay mode	Efficiencies (left) and AUCs (right) of four classifiers.							
	$e^+e^-H$		$\mu^+\mu^-H$		$\tau^+\tau^-H$		$q\bar{q}H$	
	EFF	AUC	EFF	AUC	EFF	AUC	EFF	AUC
$H \rightarrow c\bar{c}$	0.880	0.991	0.882	0.991	0.857	0.987	0.755	0.966
$H \rightarrow b\bar{b}$	0.908	0.994	0.893	0.994	0.877	0.991	0.733	0.972
$H \rightarrow \mu^+\mu^-$	0.997	1.000	0.986	1.000	0.981	1.000	0.983	1.000
$H \rightarrow \tau^+\tau^-$	0.993	0.999	0.985	0.999	0.985	0.999	0.982	0.999
$H \rightarrow gg$	0.810	0.985	0.830	0.986	0.816	0.982	0.736	0.954
$H \rightarrow \gamma\gamma$	0.997	1.000	0.999	1.000	1.000	1.000	0.997	1.000
$H \rightarrow ZZ^*$	0.650	0.958	0.667	0.960	0.585	0.947	0.535	0.926
$H \rightarrow WW^*$	0.806	0.981	0.801	0.981	0.771	0.974	0.632	0.952
$H \rightarrow \gamma Z$	0.921	0.996	0.936	0.996	0.910	0.993	0.896	0.993



# 深度学习算法在CEPC上Higgs衰变事例分类的应用

- **结果：**用ParticleNet对36个反应道和3个主要不可约本底过程进行分类：



通过这一途径进行Higgs衰变末态多分类，获取效率矩阵的方法便捷可行，为Higgs多个衰变分支比同时拟合和测量奠定基础

- 本人主要工作:
    - ✓ 部分MC样本的产生；网络的训练和优化；撰写修改部分文章
  - 本季度主要工作:
    - ✓ 根据审稿人意见改进文章内容，与编辑沟通校对文章排版
    - 文章发表于CPC(通讯作者之一): DOI: [10.1088/1674-1137/ac7f21](https://doi.org/10.1088/1674-1137/ac7f21)

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**Classify the Higgs decays with the PFN and ParticleNet at electron–positron colliders<sup>a</sup>**

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**Abstract:** Various Higgs factories are proposed to study the Higgs boson precisely and systematically as a model of the SM. The Higgs boson is the last particle to be discovered in the SM. It is the most important building block in the Standard Model (SM). The SM has been tested by many experiments and is considered to be a very successful theory to describe all fundamental phenomena. However, a precision Higgs physics program would be critically important given that the SM does not have a complete theoretical framework. The precision Higgs physics program will be able to answer questions that involve particle candidates for dark matter. The precision Higgs physics program will also be able to answer questions that involve particle candidates for new particles, gauge bosons and leptons-quarks. We are the experts probing the Higgs mechanism for generating masses [3]. In this paper, we propose to classify the Higgs decays with the PFN and ParticleNet. The Higgs boson self-coupling from the SM expectation would include new physics. The Higgs boson self-coupling from the SM expectation of a new or more detailed theoretical and experimental explanation. Various  $e^+e^-$  colliders were proposed in Higgs factories. These Higgs factories include the ones such as ILC [1], CLIC [2], FCC-ee [3] and CEPC [4, 9]. The mass of the Higgs boson ( $m_H$ ) is defined as the sum of the center of mass (CM) energy is precisely defined and that they could perform absolute measurements of the Higgs boson. Neglecting  $Z$  fusion production, in an  $e^+e^-$  collision, the Higgs boson can decay into two visible fermions or their stable decay final states ( $Z \rightarrow e^+e^-, \mu^+\mu^-, \tau^+\tau^-, \nu\bar{\nu}$ , or  $q\bar{q}$ ). The Higgs boson can be identified in the  $e^+e^-$  collision through the stable decay final states independent of the Higgs decay. For example, the  $e^+e^-$  collision can be used to measure the cross-section and ratio of the different branching fractions of the Higgs boson. The cross-section and ratio of the different branching fractions of the Higgs boson can be measured by the ParticleNet method. For example, CPC could measure the cross-section and ratio of the different branching fractions of the Higgs boson is 0.9% and the branching fractions of the Higgs boson is a few percent respectively, by combining the four decay channels.

The physical goal of a Higgs factory must be accurate enough to measure the Higgs boson properties. One of the latest developments in data science Recently, various Machine Learning (ML) techniques have already been very promising in solving problems in high energy physics [12], as particular for jet studies. For example, the ML techniques can be used to solve problems [19–22], as trees [23, 24], as graphs [25], or sets [26, 27] of particles, and ML techniques, most notably deep neural networks [28].

**Keywords:** Higgs boson, event identification, Particle Flow Network, ParticleNet

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<sup>d</sup>Copyright © Chinese Physical Society and Springer-Verlag GmbH Berlin Heidelberg 2022. This article is an open access publication

  - Bonus:
    - 在IHEP ML Innovation Group会议上开展一次ParticleNet的Tutorial

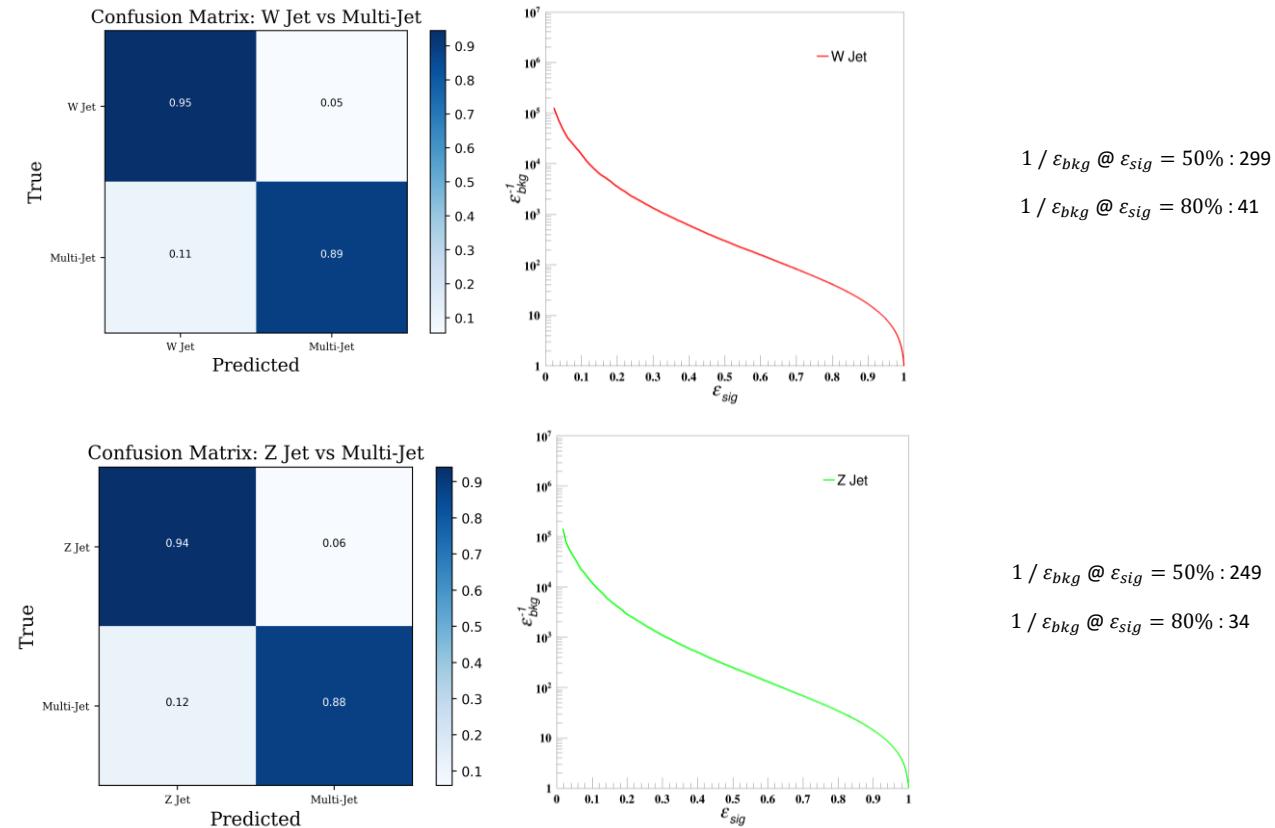
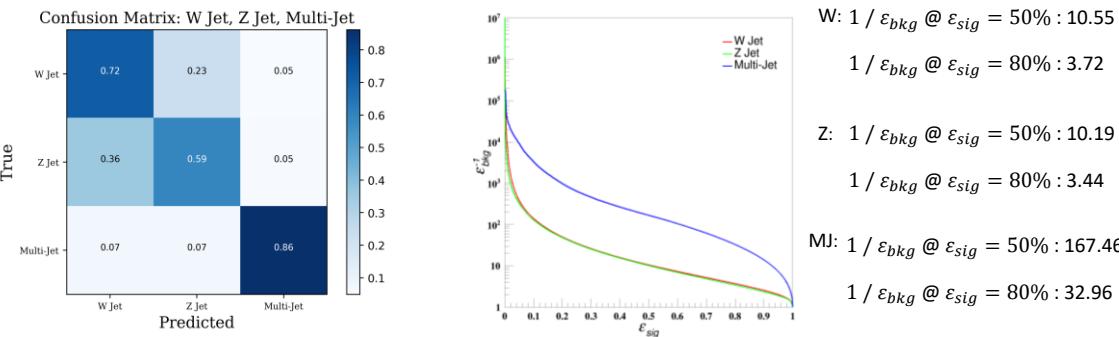
<https://indico.ihep.ac.cn/event/18059/>

# ATLAS上boosted W/Z喷注鉴别研究

- 动机：**基于粒子级信息的喷注鉴别算法，例如ParticleNet，表现强大的性能，令人印象深刻并被CMS用作官方推荐的喷注鉴别算法。在ATLAS的顶夸克喷注鉴别的相关结果中([ATL-PHYS-PUB-2022-039](#))，此类算法的性能也远超传统方法。因此，将基于粒子级信息的喷注鉴别算法，应用在ATLAS上的W/Z喷注的鉴别任务上，探索其性能表现，是自然且重要的研究课题。
- 目的：**将基于粒子级信息的喷注鉴别算法，应用在ATLAS上的boosted W/Z喷注的鉴别任务上，并最终推动其成为ATLAS官方推荐的boosted W/Z喷注鉴别方法。

## • 本季度工作进展-1：

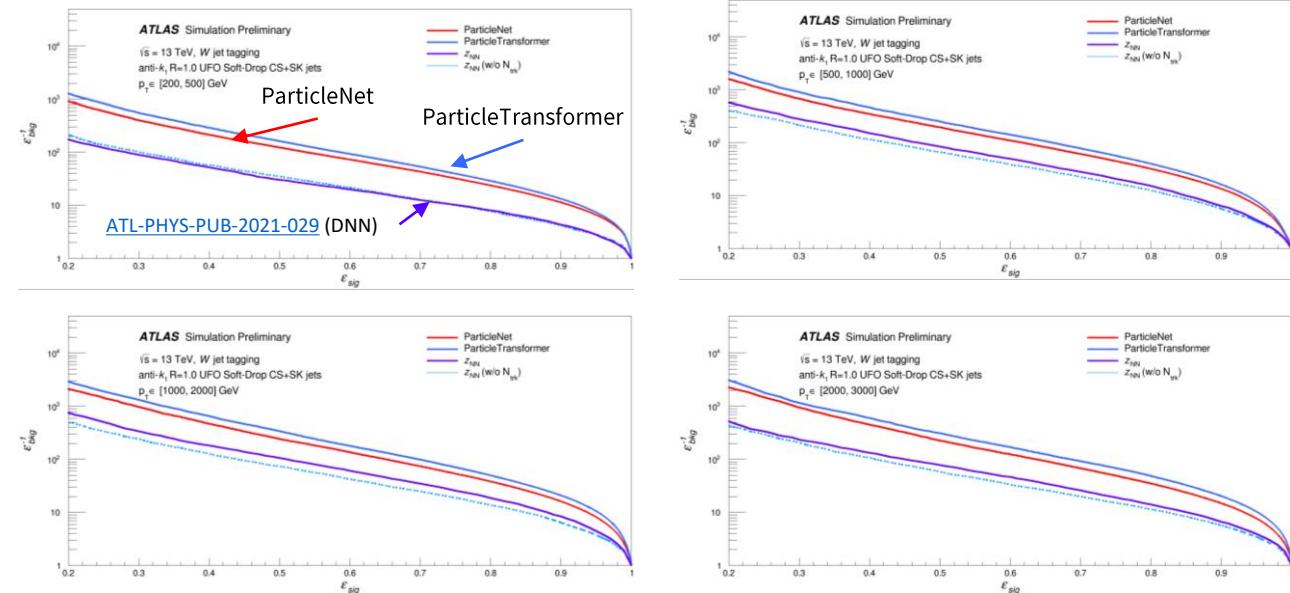
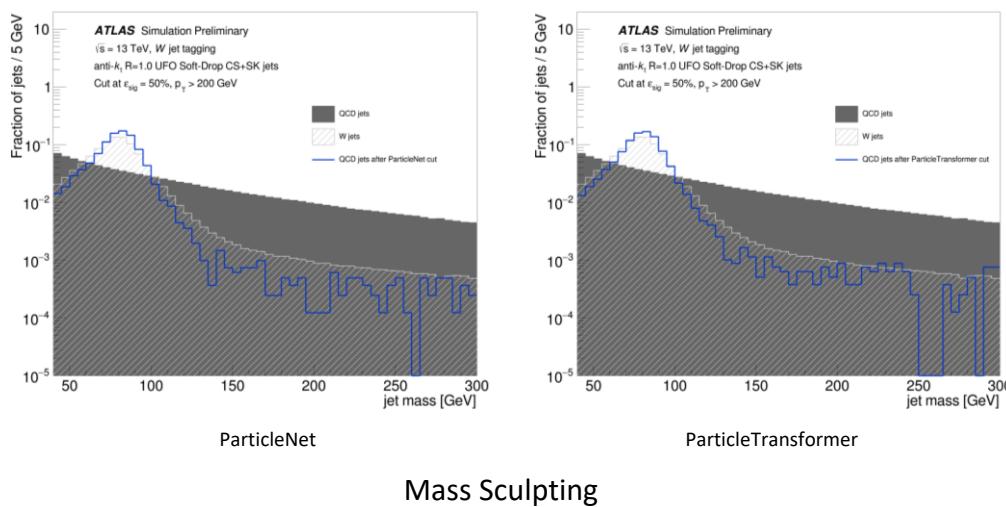
- ✓ 针对本研究发展数据预处理流程
- ✓ 应用ParticleNet和ParticleTransformer到W jet vs QCD jet、Z jet vs QCD jet和W/Z/QCD三分类任务中，初步结果显示二者的性能表现大幅超过前人工工作中 ([ATL-PHYS-PUB-2021-029](#)) 算法的性能



# ATLAS上boosted W/Z喷注鉴别研究

## 本季度工作进展-2:

- ✓ 数次在ATLAS jet tagging and scale factors combined performance group 组会上给报告
- ✓ 发现Mass Sculpting现象，与其他深度学习算法一致，将针对这一现象进行Mass Decorrelation的研究
- ✓ 将于6th ATLAS Machine Learning Forum报告该研究



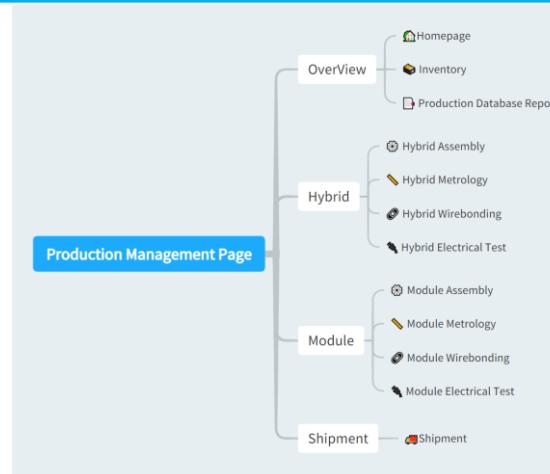
对W tagging，在 $\varepsilon_{sig}$ 相同时，rejection power平均提升~4倍

# ATLAS ITk 硅微条探测器项目中IHEP站点生产流程管理网页开发

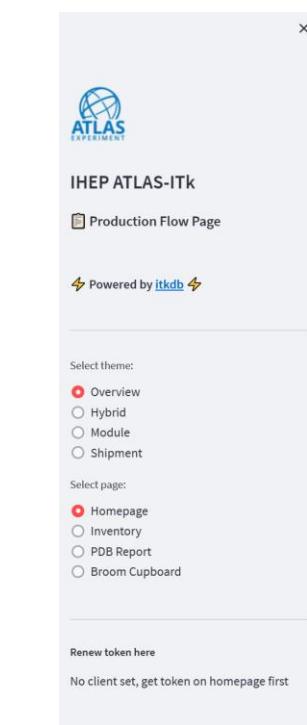
- 动机：**高能所承担的ATLAS ITk (Inner Tracker)硅微条探测器模块生产任务中，涉及大量步骤和不同的非全职操作人员，生产过程中有大量数据需要记录和上传到中央数据库。在实践中发现，生产协调管理没有规范的途径，导致生产效率低下；操作步骤繁多容易出错；数据记录方式不统一且往往与数据上传脱节，不能及时上传到中央数据库等问题。我们需要尽可能地缓解上述问题。
- 目标：**开发IHEP站点的生产流程管理网页，作为辅助性的工具提高生产效率和质量。

## • 本季度工作进展：

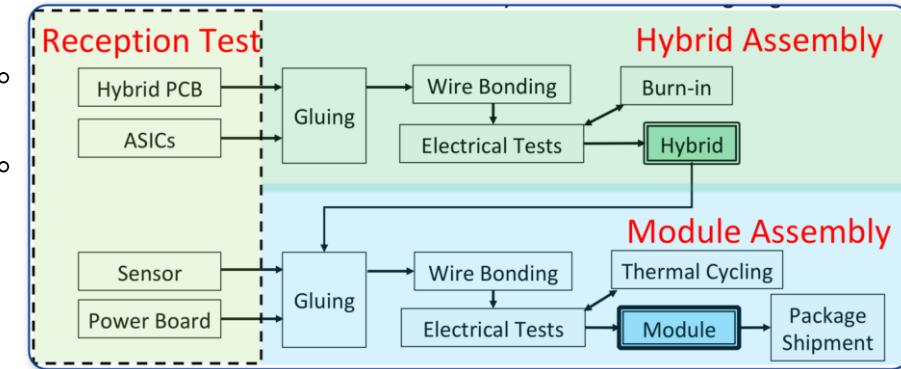
- ✓ 利用Streamlit Python包，快速搭建网页基本架构
- ✓ 实现用户登录和权限控制功能
- ✓ 实现生产任务下发和生产任务执行状态监控功能
- ✓ 已将部分生产步骤的标准操作规程写入网页，辅助操作员工作，降低误操作、漏操作的可能性
- ✓ 实现生产数据的本地结构化存储记录



2023/1/6



wangsd@ihep.ac.cn



## Homepage

## Bulletin Board

Nothing here...

## Get Your Ticket!

31 2023-01-04 @ 22:17

Enter password 1

Enter password 2

Get Token

No token yet registered

7

# ATLAS ITk 硅微条探测器CSNS站点辐照测试研究中ColdBox的设计

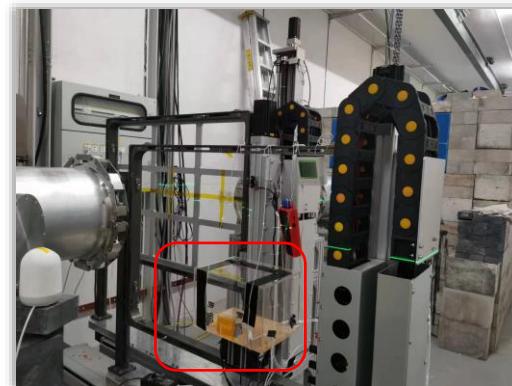
- 动机:** ATLAS ITk的硅微条探测器的探测芯片全部由Hamamatsu Photonics K.K. (HPK)生产，质量保证 ( Quality Assurance , QA) 是为了使人们相信质量要求将在生产中得到满足。我们希望验证在CSNS上的伴生质子束实验平台(Associated Proton Experiment Platform, APEP)进行质子辐照来用于ITk strip sensor的QA的可能性，并使得IHEP-CSNS成为QA站点之一。辐照测试需要一定的温湿度(-20°C, RH~10%)环境，需要设计ColdBox来提供和维持这样的环境。
- 目标:** 设计和装配能够提供符合要求的环境且可靠的ColdBox

## 本季度工作进展:

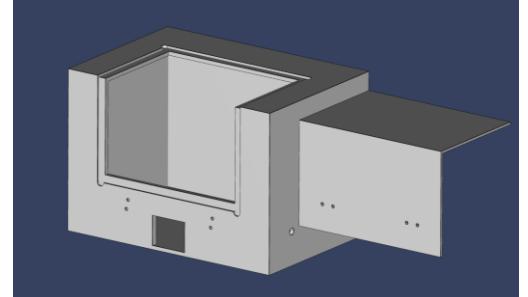
- ✓设计第一版ColdBox，利用半导体制冷片控制温度，干燥空气控制湿度，达到温湿度控制要求，已用于一次辐照测试
- ✓根据第一版的使用反馈（难以安装，气密性差，温湿度监控不便，辐照区域亚克力板老化），更新设计第二版ColdBox
- ✓由于第二版ColdBox改动较多（设计更为紧凑，提升气密性，用树莓派进行温湿度远程监控），正在利用3D打印快速生产原型以验证设计



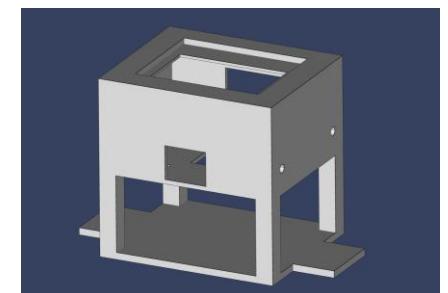
Cooler for V1



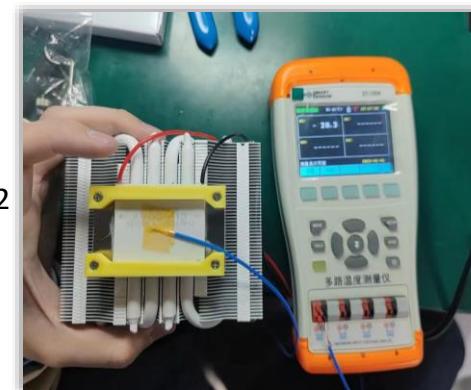
ColdBox V1 @ CSNS-APEP



ColdBox V1

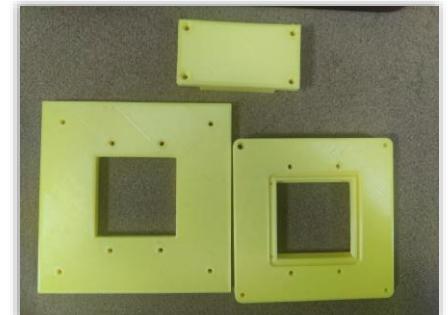


ColdBox V2



Cooler for V2

3D-printed  
mechanical prototypes

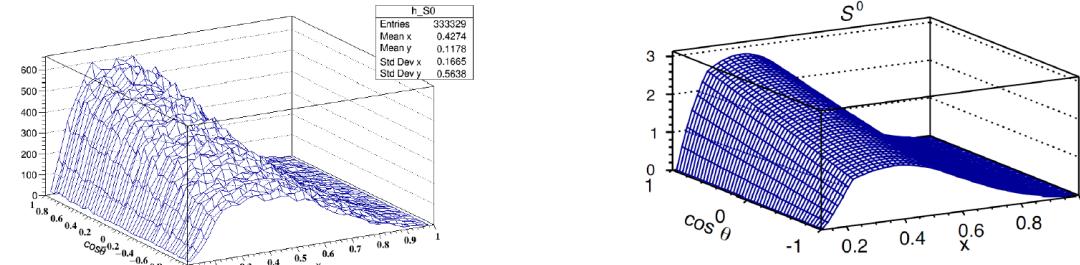


# 其他工作

- CEPC上顶夸克电弱耦合测量研究
- 目标：研究CEPC上顶夸克电弱耦合测量的灵敏度

- **本季度工作进展：**

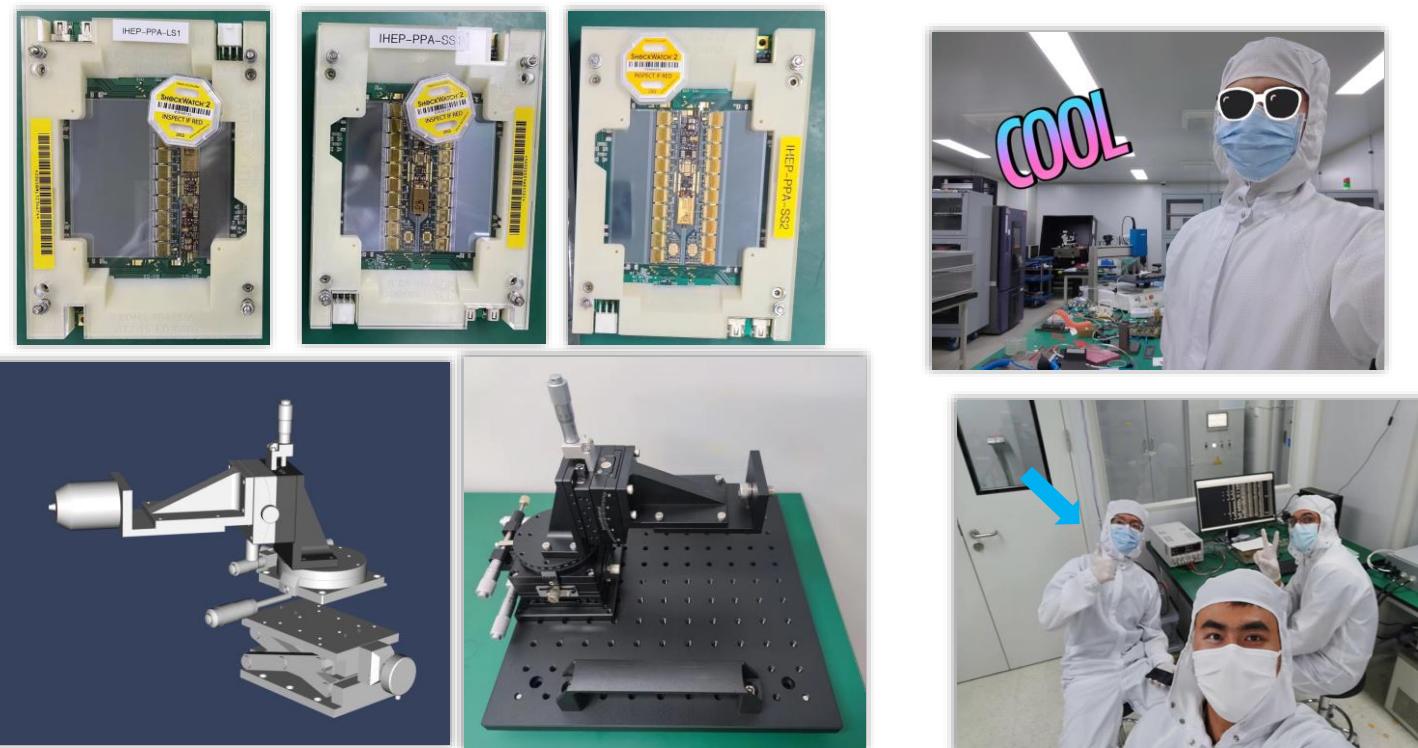
- ✓ 利用MadGraph+Pythia产生360GeV ttbar样本，检验样本中differential的正确性
- ✓ 将样本通过cepcsoft框架完成全模拟和重建



- ATLAS ITk 硅微条探测器模块生产

- **本季度工作进展：**

- ✓ 负责将Hybrid, Powerboard和Sensor组装成为Module，完成3块模块的组装：PPA-LS1, PPA-SS1, PPA-SS2
- ✓ 设计和组装bonding线修复装置
- ✓ 牵头负责根据IHEP PPB-1 production readiness review改进生产中的问题并回复意见



# 总结

- 深度学习算法在CEPC上Higgs衰变事例分类的应用
  - 相关文章完成并被CPC接收
- ATLAS上boosted W/Z喷注标记的研究
  - 在ATLAS jet tagging and scale factors combined performance group 组多次做报告
  - 初步结果显示ParticleNet和ParticleTransformer算法性能在此任务上表现大幅超过当前官方推荐算法
  - 将于6th ATLAS Machine Learning Forum报告此研究
  - 将推动其成为ATLAS官方推荐的boosted W/Z喷注鉴别方法
- ATLAS ITk 硅微条探测器项目中IHEP站点生产流程管理网页开发
  - 网页基本架构确定，权限控制、本地数据存储、任务下发与监控和部分生产步骤的标准操作规程嵌入已实现
  - 将继续迭代和完善该网页
- ATLAS ITk硅微条探测器CSNS站点辐照测试研究中ColdBox的设计
  - 第一版ColdBox完成设计制造，满足基本需求，已应用到一次辐照测试中
  - 第二版ColdBox完成初步设计，正在进行原型验证
- 其他工作
  - CEPC上顶夸克电弱耦合测量研究——完成样本产生和全模拟
  - ATLAS ITk 硅微条探测器模块生产——参与生产多个模块，设计bonding线修复工具，牵头组织回复IHEP PPB-1 production readiness review

谢谢！